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An Agile Tool for Modeling Human Performance

- **CORE (Constraint-based Optimal Reasoning Engine) introduces new flexibility in modeling and predicting performance of humans interacting with complex systems**
- **It's easy for non-experts to use, while permitting experts to select among cognitive architectures and scheduling algorithms**

The time it takes for an astronaut to perform a task on a computer, in the cockpit of a spacecraft, or on a planet with a robot may mean the difference between the mission's success or failure, and even life or death. The system interfaces that astronauts use are critical to how quickly, accurately, and safely they can do a job.

To develop and evaluate new system interfaces for future space missions, scientists at NASA are developing new, more agile technologies for modeling human performance. CICT's Intelligent Systems (IS) Project is researching the design, development, and deployment of complex human-computer systems through its Human-Centered Computing subproject, managed by Michael Shafto.

Advancing human-centered computing
"Our research teams are studying how humans, software agents, and robots all contribute to system behavior," says Shafto. "Therefore, we are looking at the computational tools, the cognitive and social systems, and the physical facilities and environments that best enable future NASA missions to succeed.

"The interface is a critical component of human-centered systems," says Shafto. "Until now, system interface design has been the domain of specialists in human performance modeling, but those people are usually not experts in designing and executing actual NASA missions. We need to find an easier way to inject real mission experience into interface design, and find more affordable and accurate ways to predict the efficacy of these interfaces with different users. We don't have the luxury of asking astronauts to spend valuable time testing new interface designs until we know they are mission-ready. To meet this challenge, Alonso Vera and his team at NASA Ames have developed the Constraint-based Optimal Reasoning Engine, or CORE."

Current challenges to modeling
Alonso Vera, principal investigator for CORE, says, "Current methods for modeling and predicting human performance either require specialized training or are too rigid to easily accommodate different possibilities. Most other cognitive architectures require that the modeler understand cognitive psychology and have sophisticated programming skills. Yet it can still take these

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CORE enables almost anyone to model new human-machine interfaces quickly and affordably. CORE automatically measures how long it would take for humans (from novice to expert) to use the interface to perform a task, as well as the probability of errors. At left is an artist's rendition of an astronaut operating a drill on a lunar exploratory mission.

Technology Spotlight

Technology
CORE—Constraint-based Optimal Reasoning Engine

Function
Enables general users to model interactive performance of humans using new computer/robotic interfaces

Relevant Missions
- Human-Robotic Exploration
- International Space Station
- Phoenix 2007 Mars Mission
- Mars Science Laboratory

Features
- "Guided-entry" interface that prompts users for input of task descriptions
- Flexible choice of cognitive architectures and scheduling algorithms
- PERT chart-style graphical output

Benefits
- Enables affordable, efficient design and evaluation of complex interface concepts without requiring working prototypes
- Supports design of software tools used in time-critical contexts
- Predicts performance for range of users—novice to expert
- Provides graphical report on time to complete task, based on skill level, and probability of user error
- Measures speed/accuracy tradeoffs
- Quantifies and validates theories of cognition

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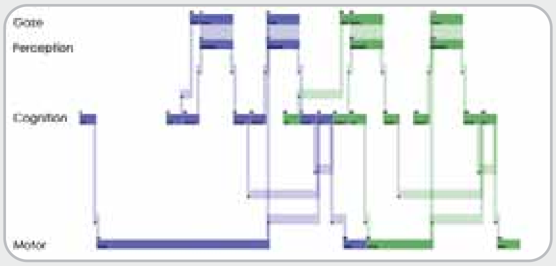

CORE produces a chart (left) that breaks the steps of a task down into its respective “operators,” showing how long each takes (in milliseconds). This chart shows how an expert begins a second step (green) before the first (blue) is complete—called “interleaving.”

experts days to develop a model, whereas we need to get it down to hours or even minutes. And, even after days of expert development, these models cannot accommodate multiple skill levels, different architectural platforms, multiple interactive users, or display tradeoffs between speed and accuracy. NASA needs a tool that is automated for use by novices, and is flexible enough to provide more output options.”

Fast and easy modeling of performance
Vera and his colleagues at NASA Ames, Irene Tollinger and Michael McCurdy, have designed CORE to simplify the process of modeling human performance for novice designers, while providing more options for experienced designers.

“CORE enables almost anyone to quickly model and predict human performance of a system task,” says Vera. “CORE predicts task times according to whether a single expert user or multiple users of different capabilities are performing it. CORE can also predict task performance given a user’s decision on how he or she wants to trade speed for accuracy, or vice versa.”

CORE’s X-PRT user interface
Irene Tollinger, who is designing the X-PRT interface for CORE, says, “X-PRT will enable even novice users to effectively create, debug, and visually verify the performance of their models. As a guided-entry interface, it assists the user in describing the essential steps in the task without imposing a particular sequence on those steps. It’s well known that as users learn a task they begin to interleave elements. For example, before finishing one step, they might glance ahead at something they are going to need in the next step. An expert user can perform the steps differently from a novice. The expert may interleave elements of two different steps.” (See illustration above.)

The X-PRT interface enables even novices to describe the task or set of tasks, the devices used (mouse, keyboard, screen, etc.), and the cognitive strategy for achieving the task, such as moving the mouse, or turning a knob, or clicking a button. The cognitive strategy can also include slow and fast moves depending on how precise a move must be.

CORE then applies embedded (but modifiable) rules and constraints to the behavioral elements of the task described, and generates a graphical chart of the optimal timing and sequence of steps in the task (see illustration above). CORE also predicts the resource requirements and total time of the activity (when the steps are done in a particular order). A designer can then revise the model to obtain better performance or adjust the tradeoff of speed vs. accuracy.

CORE provides flexibility and choice
A key feature of CORE is its flexibility. The cognitive architectures used to model human performance include implicit assumptions or rules about human performance. Take, for example, the simple task of clicking a mouse on a screen icon. Some cognitive architectures define the whole move as a single unit and proscribe the average time that will take. CORE, however, can break that move into its constituent “operators”—gaze, perception, cognition, and motor activity—and thus accommodate alternative sequences of operator events, which enables it to track and measure the benefits of expert interleaving.

CORE’s timing of the operators is based on a cognitive architecture—in this case, Card, Moran, and Newell’s Model Human Processor—but, if expert designers wish, they can select another architecture from the CORE library, or even customize an architecture by re-defining the fundamental operators and resources, as well as their parameters and dependencies.

The key is constraint satisfaction
Vera, McCurdy and Tollinger argue that it is faster and easier to predict performance from a set of architectural, strategic, environmental, and task constraints. They used that approach to model a staff-schedule data entry task for the Collaborative Information Portal, which was used successfully on a daily basis by NASA personnel on the Mars Exploration Rover mission.

“By defining these constraints separately instead of preemptively binding them to each other,” says Vera’s colleague Michael McCurdy, “we allow more flexibility in how their relationships can be computed. We also maintain their independence from arbitrary constraints imposed by the machine or the software algorithms used to model the task.”

As a result, expert designers can mix and match cognitive architectures and description languages, choosing from the options in the CORE libraries.

“CORE is an agile tool,” says Vera. “It provides novice designers with an easy-to-use modeling interface and a clear, quantifiable report on performance, while still enabling expert designers to customize the architecture to meet their own needs.”

–Larry Laufenberg

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